Sputtering Chamber and Capsule Thermal Modeling

Aaron Wemhoff
(925) 423-9839
wemhoff2@llnl.gov

The morphology of a thin film grown in a sputtering process has been shown to be heavily dependent upon the substrate temperature and the chamber conditions, as illustrated in the Thornton structure zone diagram in Fig. 1. Currently, measurements of the substrate temperature of spherical capsules in a sputtering process are extremely difficult due to the required motion of the capsule. Previous analyses for this process have involved a large number of approximations and simplifications, resulting in an uncertainty of +/- 70 ºC.

In this project, a predictive tool for the capsule temperature is investigated and applied as part of the Diablo multi-mechanics finite element code, nearly eliminating this uncertainty since the underlying mechanics of the system are captured by the code.

Project Goals

This project focuses on the full integration of all modes of heat transfer from the capsule to the surrounding chamber environment: gas adsorption, enclosure radiation, and wall-capsule contact. These modes of heat transfer are calculated using a standard finite element formulation, where the influence of each mode is designated via user-defined input variables. Furthermore, the influence of capsule motion on the aforementioned modes of heat transfer is automatically calculated at each capsule position.

Relevance to LLNL Mission

The structure of thin films is of vital importance to LLNL programs and areas of interest. Equally valuable are the addition of new features to the
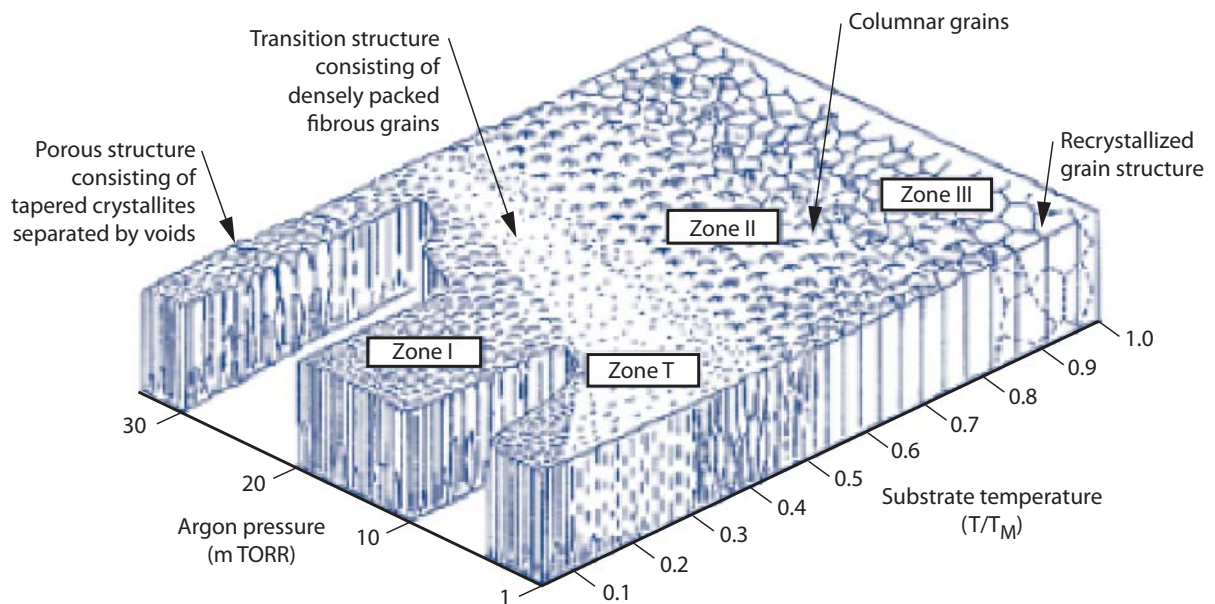

Figure 1. Thornton structure zone diagram.

Diablo code. The work performed in this project is part of a joint effort to improve the quality of sputtered films for NIF target preparation.

FY2006 Accomplishments and Results

A specialized Neumann boundary condition was added to Diablo. This module features a combination of thermal mechanics seen in the bulk node, contact, and convection algorithms. At each time-step the user-defined capsule position function allows for the automatic determination of the existence of contact, the location of contact along the chamber wall (if applicable), and the updated enclosure radiation view factor set.

View factors are efficiently calculated by projecting each facet of the chamber wall using spherical trigonometry, as seen in Fig. 2. The capsule temperature is calculated at each time-step using a standard lumped capacitance approach. The numerical approach and implementation was verified by comparing six test problems to known analytical solutions. In all cases the simulated capsule temperature agreed with the analytical solution within 0.3%.

A further test problem featured the change in capsule temperature history when the capsule was removed from the sputtering pan surface at specific times. Figure 3 shows that the change in heat loss is greatly reduced after this contact is removed, which is consistent with the reduction in heat transfer modes after the removal.

Related Reference

Thornton, J. A., "Influence of Apparatus Geometry and Deposition Conditions on the Structure and Topography of Thick Sputtered Coatings," *J. Vac. Sci. Technol.*, **11**, pp. 66-67, 1974.
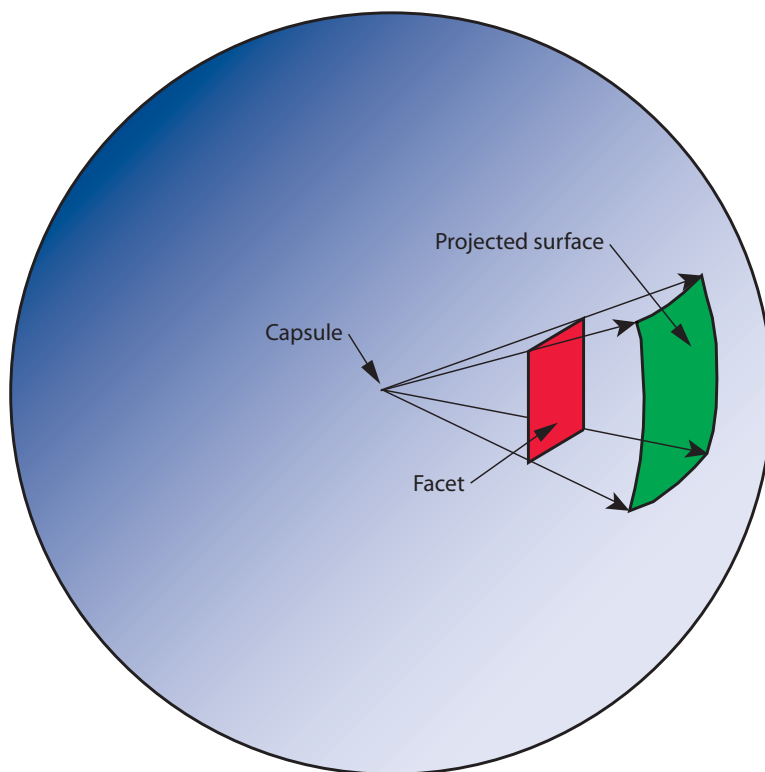

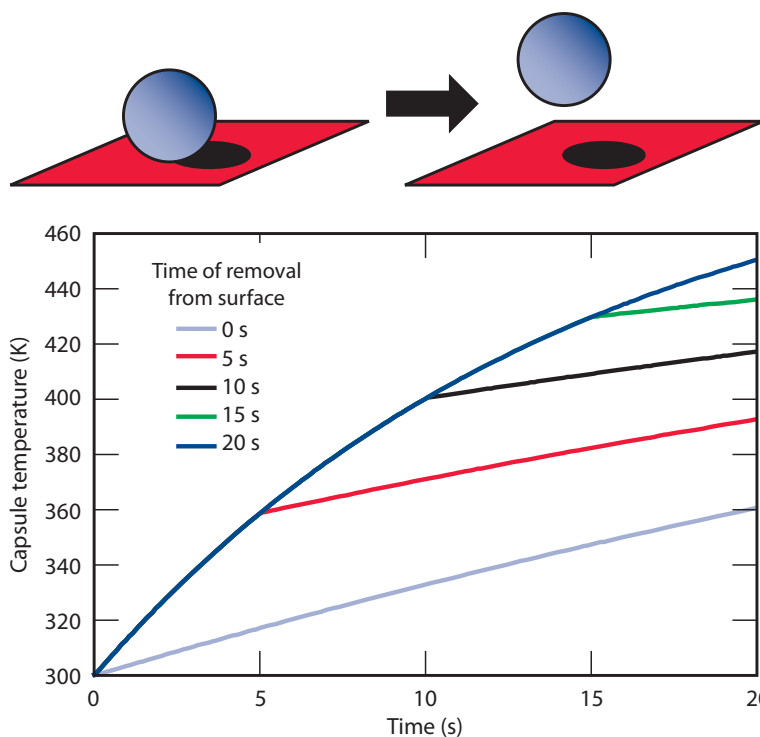**Figure 2.** Projected surface used in determination of capsule-facet view factor.

Figure 3. Temperature history of capsule for various durations of contact with the chamber wall surface.